

FATA2025: FASt Timing Applications for nuclear physics and medical imaging



Report of Abstracts

Abstract ID : 3

Key Note Speaker

Harnessing the Purcell Effect for Faster Metascintillators

Content

Recent advancements in scintillation detection and imaging have focused on two emerging concepts: metascintillators and nanophotonic scintillators. Metascintillators leverage an energy-sharing approach with at least two scintillator components: one with high stopping power and another with fast response characteristics. Conversely, nanophotonic scintillators integrate scintillating materials into nanophotonic structures to either enhance emission rates (Purcell-enhanced scintillators) or control the flow of emitted light toward detectors. Building upon these innovations, we propose integrating nanophotonic scintillators into metascintillator designs to enhance the performance of first-generation metascintillators, thus presenting a viable technological pathway toward achieving the 10 ps CTR limit in PET imaging.

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Presenter: LECOQ, Paul

Contribution Type: Oral

Status: SUBMITTED

Submitted by **LECOQ, Paul** <paul.lecoq@cern.ch> on **Monday 5 May 2025**

Abstract ID : 4

Key Note Speaker

High-Performance modular TOF-PET imager

Content

Advances in precision medicine and the need for earlier disease detection are accelerating the demand for PET imaging systems that combine high sensitivity, temporal resolution, and cost-efficiency. We introduce a new modular PET detector architecture designed to achieve exceptional time-of-flight (TOF) performance, leveraging the physical limits of modern scintillator technology. The system employs state-of-the-art silicon photomultipliers and fast, energy-efficient readout electronics to reach coincidence timing resolution (CTR) below 100 ps FWHM. This level of timing precision facilitates the deployment of flat-panel detector modules in flexible system geometries, enabling reductions in system complexity and material usage while preserving image fidelity.

Developed under the Horizon Europe EIC Pathfinder project, PetVision, this concept aims to deliver a compact, scalable TOF-PET imaging platform. This contribution will describe the project's vision, technical implementation, and progress toward a functional prototype. Supporting data from component characterisation and system-level simulations will be presented, validating the potential of this approach to rival conventional PET scanners with significantly reduced reliance on expensive scintillator material. The resulting technology offers a pathway toward adaptable PET solutions for various clinical contexts, including decentralised, mobile, and resource-limited settings.

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Contribution Type: Oral

Status: SUBMITTED

Submitted by **PESTOTNIK, Rok** <rok.pestotnik@ijs.si> on **Sunday 11 May 2025**

Abstract ID : 5

Towards a sub-100 ps ToF-PET module using the FastIC+ ASIC

Content

Time-of-flight Positron Emission Tomography (ToF-PET) has become an essential tool in medical imaging in recent years thanks to the improvement on the spatial resolution and the Signal-to-Noise Ratio of PET scans compared to conventional PET systems. A key parameter for achieving high image quality in ToF-PET is the Coincidence Time Resolution (CTR), which depends not only on the scintillator and photosensor employed but also on the performance of the front-end electronics.

In this context, we present the FastIC+, a low-power, multi-channel front-end ASIC featuring an integrated Time-to-Digital Converter, specifically designed for fast timing applications. This contribution will report the excellent timing performance of FastIC+, achieving sub-100 ps CTR values when coupling $3 \times 3 \text{ mm}^2$ silicon photomultipliers to small scintillation crystals ($2 \times 2 \times 3 \text{ mm}^3$), and sub-140 ps with crystals up to 20 mm in length. The on-chip digitization sets an important milestone toward the implementation on larger systems involving thousands of detectors, where power efficiency and integration density are critical. The scalability of this approach will also be covered in the talk.

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Contribution Type: Oral

Status: SUBMITTED

Submitted by **MAZZANTI TARANCÓN, David** <dmazzanti@icc.ub.edu> on **Friday 16 May 2025**

Abstract ID : 6

Nuclear physics measurements in laser-induced hard electromagnetic background

Content

The advent of new techniques in laser amplification triggered many laboratories to start new projects to study plasmas with temperatures and pressures close to those existing only in astrophysical sites. This has attracted the interest of the nuclear astrophysics community since it could unlock the measurement of cross-sections in an environment similar to the astrophysical ones, where the electrons and ions are mostly separated and the electron screening contribution has to be evaluated. A laser experiment is very different from a standard nuclear physics experiment with an accelerator and cold gas, liquid or solid targets. The background induced by a high-intensity high-power laser can in some cases represent a strong hindrance to the study of nuclear reactions, especially at the energies of interest for nuclear astrophysics. To overcome this difficulty, the ToF technique is used since it helps to disentangle the expected signal from the main source of laser-induced background. This is mainly due to the hard-X/gamma peak and the strong electromagnetic pulse (EMP) following the sudden ionization of the target (and the generation of a plasma). While the former can be disentangled by moving far away the detectors provided you have sufficient solid angle coverage, the latter is preventing the use of any sensitive electronics (such as sensitive spectroscopic amplifiers, complex integrated devices), sometimes even behind concrete walls. A small review of the ToF detectors commonly used to detect charged particles and neutrons coming from nuclear reactions occurring in such an environment will be given, with a special focus on the nuclear astrophysics case. Some successful results, open problems, ongoing campaigns and future projects will be discussed.

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Contribution Type: Oral

Status: SUBMITTED

Submitted by **LATTUADA, Dario** <lattuada@lns.infn.it> on **Wednesday 25 June 2025**

Abstract ID : 7

Key Note Speaker

State-of-the-art of Time-of-Flight spectrometers used in fission, quasi-fission and multinucleon transfer experiments for the study of heavy and superheavy elements

Content

Fission, quasi-fission and multinucleon transfer reactions in heavy ion collisions at energies around the Coulomb barrier are types of two-body reactions. The observables of main importance are the primary masses of the products and their total kinetic energy. Given the energy and mass respective ranges, the Time-Of-Flight (TOF) method is the detection method of choice because it can guarantee mass and energy resolution of few mass units and around 10 MeV, respectively.

A Time-Of-Flight (TOF) spectrometer is a tool to measure velocities and directions of motion of travelling particles. Usually this is accomplished by using a detector that gives a signal when the particle passes through, the Start detector, followed, at a certain fixed distance, by the Stop detector that gives a signal when the particle hits it. The set of Start and Stop detectors is usually called a TOF arm. In the most advanced spectrometers, the Start detector has a reduced size and can stand at high particle rates, while the Stop detector is position sensitive at the scope of measuring, with a fair accuracy, the length of the flight path and the angle of motion with respect to the beam direction. The Start detector is usually non-position sensitive, and the particles do not punch through the Stop detector.

One of the most productive TOF spectrometers is based on the CORSET project [1] which consists of 2 arms, each one containing a Start and a Stop detector. Only the Stop detectors are position sensitive. The time of flight and the position of the fragments in each respective arm along with the two-body kinematics allows the reconstruction of the mass and kinetic energies of the primary fragments. The Start and Stop detectors use a system of microchannel plates to achieve a fast time resolution (~150 ps). It is possible to reach a mass resolution up to 2-4 amu with a flight path of 20 cm.

In the presentation, we will discuss the features of the CORSET spectrometer, and a new implementation of the TOF method, the TOSCA project [2]. This latter is based on a unit which can measure the position of the traveling fragments without stopping them and is equipped with digital electronics. A possible implementation of the TOSCA units in a new type of spectrometer that can also measure the charge of the ions will be presented as well.

1. E.M. Kozulin et al., Instrum. Exp. Tech., 51(2008) 44
2. E. Vardaci et al., in preparation (2025)

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Contribution Type: Oral

Status: SUBMITTED

Submitted by **VARDACI, Emanuele** <emanuele.vardaci@na.infn.it> on **Wednesday 25 June 2025**

Abstract ID : 8

MONOLITH - picosecond capability in a high granularity monolithic silicon pixel detector

Content

The MONOLITH H2020 ERC Advanced project aims at producing a high-granularity monolithic silicon pixel detector with picosecond-level time stamping. Such extreme timing exploits: i) fast and low-noise SiGe BiCMOS electronics; ii) a novel sensor concept: the Picosecond Avalanche Detector (PicoAD), that uses a patented multi-PN junction to engineer the electric field and produce a continuous gain layer deep in the sensor volume. The result is an ultra-fast current signal with low intrinsic jitter in a full fill factor sensor.

A testbeam with minimum-ionising particles of the monolithic PicoAD prototype provided full efficiency and 11.5 ps time resolution.

In addition, a prototype without internal gain layer was produced featuring the same SiGe HBT electronics. Testbeam measurements showed full efficiency and 20 ps time resolution at a power consumption of 0.9 W/cm^2 and a sensor bias voltage $\text{HV} = 200 \text{ V}$. This prototype after being irradiated up to $1 \cdot 10^{16} \text{ neq/cm}^2$, still provides an efficiency of 99.7% and 45 ps at $\text{HV} = 300 \text{ V}$.

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Presenters: CARDELLA, Roberto (University of Geneva); IACOBUCCI, Giuseppe (University of Geneva)

Contribution Type: Oral

Status: SUBMITTED

Submitted by **CARDELLA, Roberto** <roberto.cardella@unige.ch> on **Wednesday 25 June 2025**

Abstract ID : 9

100μPET: an ultra-high-resolution silicon-pixel-based PET scanner

Content

The 100μPET project is developing a pre-clinical medical scanner for positron-emission tomography (PET) with ultra-high-resolution molecular imaging capabilities. The scanner is composed of multiple layers of monolithic active pixel sensors (MAPS) connected to flexible printed circuits (FPC). With pixels of 150 μm pitch and a thickness of 280 μm + 300 μm (MAPS + FPC), the scanner achieves unprecedented volumetric spatial resolution of 0.02 mm³, one order of magnitude better than the best current PET scanners, and offers uniform resolution along the scanner's field-of-view (parallax free). This work presents the project with focus on the MAPS design challenges and characterization results. The chip features ~25k hexagonal pixels with 93 μm side in 130 nm SiGe BiCMOS. The in-pixel frontend achieves an ENC < 200 electrons, with 200-ps-level jitter and power consumption below 100 mW/cm². The ASIC includes 150 ps resolution TDCs, a pipelined 50 MHz projection-based readout, and handshaking protocol for daisy-chained, single line readout.

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Presenter: CARDELLA, Roberto (University of Geneva)

Contribution Type: Oral

Status: SUBMITTED

Submitted by **CARDELLA, Roberto** <roberto.cardella@unige.ch> on **Wednesday 25 June 2025**

Abstract ID : 10

HRPPD photosensors for Nuclear Physics detectors and TOF PET imaging

Content

High Rate Picosecond Photodetectors (HRPPDs) are Micro-Channel Plate (MCP) based DC-coupled photosensors recently introduced by Incom, Inc. that have an active area of 104 mm by 104 mm, pixel pitch 3.25 mm and timing resolution up to 15-20 ps for a single photon detection. As such, these photosensors are very well suited for Ring Imaging Cherenkov (RICH) detectors with a high resolution timing capability, and Time of Flight detectors in Nuclear Physics experiments, as well as they have a potential to be used in Time of Flight Positron Emission Tomography.

Recently, a new version of HRPPDs has been developed that were substantially re-designed for use at the Electron-Ion Collider (EIC), which will be sited at Brookhaven National Laboratory in the US. A first batch of seven “EIC HRPPDs” was manufactured by Incom, Inc. in 2024. Results of a systematic evaluation of these first EIC HRPPD tiles, including gain and quantum efficiency non-uniformity, timing resolution, dark count rates, and performance in a high magnetic field will be presented. First commissioning results from a TOF PET demo setup, with a pair of LYSO crystal matrices and HRPPDs detecting $\gamma\gamma$ coincidence events resulting from a ^{22}Na source positron emission decay will be shown, as well as future plans will be discussed.

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Contribution Type: Oral

Status: SUBMITTED

Submitted by **KISELEV, Alexander** <ayk@bnl.gov> on **Thursday 26 June 2025**

Abstract ID : 11

Key Note Speaker

Fast-timing technology in non-linear and super-resolution microscopy

Content

Fast-timing technology has been implemented in non-linear and super-resolution laser scanning microscopy to improve several imaging methods. The fast or ultrafast time information point-by-point can be translated into better spatial resolution and more quantitative data about the physical processes occurring in that defined spatial position. In order to acquire such data, specialized hardware is required. Depending on the method used, single photon detectors or detector arrays are required; TCSPC or fast FPGA board or lock-in amplifiers should serve for data process and acquisition; pulsed visible laser or ultrafast femtosecond are needed to trigger the photophysical processes, which give the contrast for the image formation. The seminar will discuss about image scanning microscopy (ISM), its ability to measure fluorescence lifetime (FL)[1], and its combination with two-photon excitation fluorescence microscopy (2PEFM)[2]. The ISM exploits a SPAD array to replace the confocal pinhole, and the resulting image is reconstructed by pixel reassignment. Such a method, while improving the spatial resolution, allows measuring FL at a higher signal-to-noise ratio.

Moreover, the use of ultrafast femtosecond lasers for two-photon excitation opens the discussion on other non-linear contrast mechanisms, such as transient absorption. Its measure can be realized by pump-probe spectroscopy, a time-resolved method used to study dynamic processes in materials. Its implementation in a scanning microscope and the exploitation of absorption saturation allows it to bring the spatial resolution down to tens of nanometers using NIR light [3].

1. Castello M, Tortarolo G, Buttafava M, Deguchi T, Villa F, Koho S, Pesce L, Oneto M, Pelicci S, Lanzanó L, Bianchini P, Sheppard CJR, Diaspro A, Tosi A, Vicidomini G. A robust and versatile platform for image scanning microscopy enabling super-resolution FLIM. *Nat Methods*. 2019 Feb;16(2):175–8.
2. Koho SV, Slenders E, Tortarolo G, Castello M, Buttafava M, Villa F, Tcarenkova E, Ameloot M, Bianchini P, Sheppard CJR, Diaspro A, Tosi A, Vicidomini G. Two-photon image-scanning microscopy with SPAD array and blind image reconstruction. *Biomed Opt Express*. 2020;11(6):2905.
3. Zanini G, Korobchevskaya K, Deguchi T, Diaspro A, Bianchini P. Label-Free Optical Nanoscopy of Single-Layer Graphene. *Acs Nano*. 2019 Aug 27;13(8):9673–81.

Author: BIANCHINI, Paolo (Fondazione Istituto Italiano di Tecnologia)

Co-authors: Dr CASTELLO, Marco (Genoa Instruments s.r.l.); Prof. DIASPRO, Alberto (Fondazione Istituto Italiano di Tecnologia)

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Contribution Type: Oral

Status: SUBMITTED

Submitted by **BIANCHINI, Paolo** <paolo.bianchini@iit.it> on **Friday 27 June 2025**

Abstract ID : 12

The “pixelation technique” in the Timing Analysis of the data collected by the FARCOS correlator in the CHIFAR experiment

Content

The main aim of the CHIFAR experiment, carried out at INFN-LNS, was the investigation of the emission probability of Intermediate Mass Fragments (IMFs) in non-central Heavy Ion collisions. This phenomenon is linked to the features of the Equation of State of the nuclear matter, focusing also on the role of the isospin degree of freedom of the colliding nuclei. The CHIMERA collaboration has investigated six nuclear reactions at 20 A MeV beam energy, achieved by combining three beams - ^{124}Sn , ^{112}Sn and ^{124}Xe - and three targets - ^{64}Ni , ^{58}Ni and ^{64}Zn .

The experimental setup consisted of the CHIMERA multi-detector coupled to 10 telescopes of the FARCOS (Femtoscope ARray for CORrelations and Spectroscopy) correlator. The triple array configuration of FARCOS is based on 2 DSSSDs (Double Sided Silicon Strip Detectors, 300-1500 μm thick, respectively) and 4 CsI crystals (6 cm thick). The high energy and angular resolution of FARCOS make it an appropriate tool for intended research: the IMFs can be identified up to $Z \sim 16$, and furthermore the coupling with CHIMERA allows to study correlations among IMFs and light charged particles produced in the nuclear reactions.

The contribution will explain the results obtained by the “pixelation” technique. According to a timing analysis applied to the data collected by the two DSSSDs, the position of each detected particle can be assigned unambiguously, from the crossing of a strip of the front side to another of the back side, considering its angles in the laboratory frame (polar angle θ and azimuthal angle ϕ).

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Presenter: ZAGAMI, Cristina (Dip. Fisica e Astronomia Università di Catania & INFN-LNS)

Contribution Type: Oral

Status: SUBMITTED

Submitted by **ZAGAMI, Cristina** <crisrina.zagami@lns.infn.it> on **Saturday 28 June 2025**

Abstract ID : 13

Development of Hybrid and CMOS Monolithic LGADs for the 20 ps TOF detector of the future ALICE3 experiment at the LHC

Content

This talk will present key results and future directions in the development of both traditional and monolithic Low Gain Avalanche Detectors (LGADs and CMOS-LGADs).

Advances in silicon detector technology have led to significant improvements in timing precision. Nevertheless, the demanding requirements of next-generation experiments - and their broader relevance to future projects such as the FCC-ee - have driven dedicated R&D efforts to achieve an even better performance. For the proposed ALICE 3 experiment at the CERN-LHC (to be installed during LS4 in 2034-35), an intensive research program is focused on developing a sensor technology capable of providing a 20-picosecond time resolution for the Time-Of-Flight (TOF) detector. The R&D campaign, which demonstrated excellent performance across different LGAD layouts and led to sensors meeting the ALICE3 requirements, will be presented. Detailed studies were performed on progressively thinner LGAD sensors, including the first 15 μ m-LGADs ever produced by FBK (Fondazione Bruno Kessler), Trento, Italy. The results demonstrated that thinner designs can significantly improve timing performance, achieving resolutions below 20ps.

In addition, to overcome the challenge of reduced signal amplitude at the front-end electronics input, the novel double-LGAD concept was developed and tested for the first time. Furthermore, investigations of the impact of particle incidence angle yielded valuable insights for optimizing the detector design.

In parallel, substantial progress has been made in extending the LGAD concept to CMOS technology. CMOS-LGAD design offers a potentially transformative path forward, enabling the combination of precise timing and full-area coverage in a monolithic approach, resulting in simpler and more cost-effective assembly. The first CMOS-LGAD prototypes were produced during the third ARCADIA engineering run using LFoundry's 110nm technology and were tested for the first time. These initial low-gain batches provided valuable benchmarks for refining sensor optimization strategies. Building on these developments, the latest CMOS-LGAD devices, with gains up to 14, have achieved an intrinsic sensor time resolution of 75ps. The talk will finally outline the next steps in this development roadmap, focusing on strategies to close the remaining performance gap and achieve the target 20ps resolution also with this new technology implementation.

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Contribution Type: Oral

Status: SUBMITTED

Submitted by **STRAZZI, Sofia** <sofia.strazzi@cern.ch> on **Sunday 29 June 2025**

Abstract ID : 14

High-Resolution Timing with the CAEN A5203B in the ProVision PET scanner

Content

Precision timing is a key requirement in both nuclear physics and medical imaging applications, such as Time-of-Flight Positron Emission Tomography (TOF-PET). The CAEN A5203B, part of the FERS (Front-End Readout System) platform, integrates two CERN picoTDC ASICs in a compact and scalable unit capable of high-resolution Time of Arrival (ToA) and Time over Threshold (ToT) measurements over 128 channels.

In this work, we present the implementation and performance of the A5203B module in the ProVision PET scanner, a compact imaging system developed within the Eureka Eurostars program for early-stage detection of aggressive prostate cancer. The scanner architecture consists of two planar detector heads, each equipped with 768 SiPM channels read out by six A5203B modules, and synchronized through a DT5215 Concentrator Board.

Experimental validation includes laboratory tests with signal generators and the CAEN A5256 adapter, as well as system-level measurements within the ProVision PET prototype. The results demonstrate sub-200 ps coincidence time resolution, accurate ToT-based amplitude reconstruction, effective noise suppression, and high-throughput readout with minimal dead time. These findings confirm the suitability of the A5203B module as a high-performance solution for time-critical applications in both clinical and research-oriented TOF-PET systems, as well as perfect fitting in high-resolution timing applications in nuclear and particle physics.

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Co-authors: Dr DOROUD, Katayoun (Picotech SaS); MATI, Annalisa (CAEN SpA); Dr NINCI, Daniele (CAEN SpA); TINTORI, Carlo; VENTURINI, Yuri (CAEN SpA); Dr WILLIAMS, Crispin (Picotech SaS); Dr WILLIAMS, Themis (Former member of Picotech SaS)

Presenter: Dr MAGGIO, Camilla (CAEN SpA)

Contribution Type: Oral

Status: SUBMITTED

Submitted by **MAGGIO, Camilla** <c.maggio@caen.it> on **Monday 30 June 2025**

Abstract ID : 15

Silicon carbide detectors for accurate temporal structure pulsed beam monitoring in FLASH radiotherapy

Content

The use of ultra-intense high flux particle beams (10⁹-10¹⁴ particles/s mm²), named ultra-high dose rate beams (UHDR) (> 40 Gy/s) in radiotherapy, exhibits the so-called “FLASH effect” which reduces the surrounding healthy tissues toxicity inducing the same biological damage to the tumoral target in comparison to conventional radiotherapy. This innovative technique named FLASH radiotherapy (FLASH-RT), faces several challenges in particle detection, dosimetry and beam monitoring due to the observed saturation effects occurring in most of the traditional dosimeters and detectors (mainly ionization chambers but also solid state diodes) at these high dose rates. Silicon Carbide (SiC) detectors recently developed at the INFN Catania division in collaboration with the STLab startup, have been demonstrated to be dose-rate independent up to an instantaneous dose rate of 5.5 MGy/s (corresponding to about 10¹⁴ particles/s mm²), emerging as a reliable alternative technology for dosimetry in FLASH-RT [1,2]. In recent studies we also explored the suitability of using the SiC detectors for monitoring the intra-pulse instantaneous beam current and measure the temporal structure of electron and ion pulsed beams, crucial for monitoring the possible fluctuations of the instantaneous dose rate occurring within the pulse. Experiments were conducted using the UHDR electron beams accelerated at 9 MeV by an ElectronFlash linac at the Centro Pisano for Flash Radiotherapy and varying different beam parameters, such as the beam current (i.e., different charge per single pulse) and pulse width settings (0.5-4 us). The temporal structure of the single pulse was measured with a 10 µm thick, 4.5 mm² area SiC detector for different configurations and compared with well-established AC Current Transformer toroids (ACCTs), serving as the standard monitoring system of the accelerator. The results show a high level of agreement between the signals of the SiC detector and ACCT and a very good time resolution (<10 ns) [3]. A recent experiment was also carried out using the short (<1 us) pulsed carbon ion beam at the GSI laboratory. These results highlighted the potential of the SiC detectors to be used for temporal measurement at high time resolution and for real time measure the instantaneous dose rate, a crucial clinical parameter for such emerging FLASH-RT technique.

[1] Romano F, Milluzzo G, DiMartino F, et al. First characterization of novel silicon carbide detectors with ultra-high dose rate electron beams for FLASH radiotherapy. *Appl Sci.* 2023;13(5):2986.

[2] Milluzzo G, De Napoli M, Di Martino F, et al. Comprehensive dosimetric characterization of novel silicon carbide detectors with UHDR electron beams for FLASH radiotherapy. *Med Phys.* 2024;1-12.

[3] C. Okpuwe, G. Milluzzo et al., Systematic Study of Silicon Carbide Detectors and Beam Current Transformer Signals for UHDR Single Electron Pulse Monitoring, *Radiation Research* 203(4), 236-245, (25 February 2025)

Author: MILLUZZO, Giuliana Giuseppina (Istituto Nazionale di Fisica Nucleare)

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Contribution Type: Oral

Status: SUBMITTED

Submitted by **MILLUZZO, Giuliana Giuseppina** <giuliana.milluzzo@ct.infn.it> on **Monday 7 July 2025**

Abstract ID : 16

Timing performance of Timepix4, a large area four side buttable pixel detector readout chip

Content

Timepix4 is the latest application-specific integrated circuit (ASIC) in the Medipix family, developed by the Medipix4 Collaboration for high-resolution, single-particle detection in hybrid pixel detectors [1]. It features a 448×512 pixel matrix with integrated analog and digital front-end electronics, and a data-driven architecture capable of handling data rates up to 160 Gb/s. With a pixel pitch of $55 \mu\text{m}$ and a Time-to-Digital Converter (TDC) bin size of 195 ps, Timepix4 allows to simultaneously excellent spatial and timing resolution.

The timing performance of several Timepix4 assemblies has been characterized [2]. External test pulses were used to evaluate the digital front-end contribution and to precisely measure the TDC bin size. The internal test-pulse system was employed to assess the analog front-end jitter in both bare ASICs and those bonded to silicon sensors. Jitter below the TDC resolution of 55 ps was achieved when collecting electrons, and a timing resolution of 105 ps was observed when configured to collect holes.

Further evaluation was performed on a Timepix4 assembly bump-bonded to a $100\text{-}\mu\text{m}$ thick n-on-p silicon sensor [3]. A picosecond pulsed infrared laser was used to generate electron-hole pairs within the silicon bulk in a controlled and repeatable manner, enabling precise regulation of the signal's magnitude, position, and timing. A single-pixel timing resolution of 107 ps r.m.s. was measured for laser-induced signals. By exploiting multi-pixel clustering and oversampling timing information across several pixels, the resolution was improved to 33 ps r.m.s.

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Contribution Type: Oral

Status: SUBMITTED

Submitted by **BOLZONELLA, Riccardo** <rbolzonella@fe.infn.it> on **Monday 7 July 2025**

Abstract ID : 17

Fast Timing with SiC detector arrays for high-intensity Radioactive Ion Beam experiments

Content

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Fast timing is an important requirement in nuclear physics experiments, particularly for the identification of Radioactive Ion Beams (RIBs) [1–7]. Thanks to the SAMOTHRACE ecosystem [8], silicon carbide (SiC) detector arrays are being developed to address the specific challenges of RIBs identification, with applications in both nuclear and medical physics [3,6,7]. The detection system is intended to be usable at several international facilities, including FraISE (Fragment In-flight Separator), currently under construction at INFN-LNS to deliver high-intensity (10^3 – 10^7 pps) RIBs [3]. This system, integrated with fast front-end electronics [9–10], is designed to provide precise measurements of RIBs (composition, energy and beam-profile) and to operate in harsh environments [3]. An important feature of the detection system is the high timing performance (<200 ps), which enables the measurement of the RIBs energy with a resolution of about 0.5%. This contribution presents a comprehensive study of the timing performance of SiC detectors composed of 2×2 pixels, with a total area of 1 cm^2 and a thickness of $100 \mu\text{m}$. The results are the outcome of several years of R&D and include measurements with radioactive alpha sources, as well as accelerated proton and alpha beams. A novel method, based on crossing-time determination and signal-sharing analysis, has been employed to extract the time resolution of individual SiC pixels. A comparative study with a microchannel plate (MCP) detector, operated in coincidence with the SiC detector, will also be discussed [11]. Furthermore, preliminary results from a recent experiment conducted at the Heavy Ion Laboratory (HIL) in Warsaw, using the $^{12}\text{C} + ^{12}\text{C}$ reaction at 73 MeV, will be presented.

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Contribution Type: Oral

Comments:

Invited

Status: SUBMITTED

Submitted by **MARTORANA, Nunzia Simona** <nunzia.martorana@ct.infn.it> on **Monday 14 July 2025**

Abstract ID : 18

Research and development on TOF-PET through Cherenkov and scintillation emission

Content

Time-of-Flight Positron Emission Tomography (TOF-PET) is among the most advanced medical imaging technologies, offering enhanced image reconstruction through precise measurement of photon flight times following positron-electron annihilation. The exploitation of ultrafast Cherenkov radiation, characterized by the prompt emission of photons, represents a promising route for improving the temporal resolution of TOF-PET systems [1].

Capitalizing on this potential requires the development of fast photosensors with extended UV sensitivity and single-photon detection capabilities. These devices must offer fast response times, low jitter, and high quantum efficiency within the Cherenkov spectral domain, allowing for significant reduction in time uncertainty and improved spatial localization [2].

In this work, we report on the design and characterization of advanced detection modules based on scintillator and Cherenkov radiators—namely CeBr_3 , BaF_2 , and PbF_2 crystals—configured in 8×8 matrices with elements of $1 \times 1 \times 3 \text{ cm}^3$. These matrices are coupled either to large-area silicon photomultipliers (SiPMs) or to silicon carbide avalanche photodiodes (SiC-APDs), which offer intrinsic benefits in terms of timing stability and radiation hardness [4][5]. Readout is performed via FERS-TDC A5204 electronics, capable of individual channel discrimination and picosecond-level timing resolution over 64 channels per board [6].

The integration of these detector systems, currently under development and testing, aims to achieve single-photon Cherenkov timing resolution of the order of tens of picosecond paving the way for the next generation of TOF-PET scanners with enhanced image quality, lower radiation dose.

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Contribution Type: Oral

Status: SUBMITTED

Submitted by **PAGANO, Emanuele Vincenzo** <epagano@lns.infn.it> on **Monday 14 July 2025**

Abstract ID : 20

Neutron detection in reactions with relativistic radioactive beams

Content

The R3B (Reactions with Relativistic Radioactive Beams) setup for kinematically complete measurements of reactions with very short-lived beams has been developed at GSI/FAIR. High versatility is obtained by different detectors of particles from photons, protons and neutrons to heavy nuclei. One of the key detectors is the neutron detector NeuLAND (New Large Area Neutron Detector) [\[1\]](#) capable of multi-neutron detection with high precision and efficiency. Its modular design allows measurements with smaller versions of the detector during the long construction phase. Already the NeuLAND Prototype (with 13% of the complete detector) has been successfully used in experiments at RIKEN [\[2\]](#). Since then, it has been constantly upgraded in volume and used in the experiments at GSI/FAIR within the Phase-0 physics program. The performance of NeuLAND will be outlined in the results of the analysis of NeuLAND commissioning and measurements studying the symmetry energy at saturation [\[3\]](#) and suprasaturation [\[4\]](#) nuclear density with an emphasis on the recognition of multineutron events.

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Submitted by **PAGANO, Emanuele Vincenzo** <epagano@lns.infn.it> on **Friday 18 July 2025**

Abstract ID : 21

Timing performance of the Multigap Resistive Plate Chambers for the cosmic ray telescopes of the EEE Project

Content

The Extreme Energy Events (EEE) Project has built since 2004 a GPS-synchronized network of cosmic ray telescopes based on Multigap Resistive Plate Chambers (MRPC), which are distributed over the Italian territory. Most of them, installed within high school institutes and operated by local teams of students and teachers, are still operating today, after more than 15 years of data taking. Various upgrades, also concerned with the use of new eco-friendly gas mixtures have been undertaken, to reduce the impact of the traditional gases with high Global Warming Power.

Good tracking, efficiency and timing capabilities of the MRPCs and the associated electronics used in the project have allowed a variety of physics investigations, accompanied by an intense outreach programme over the last years. After the early cosmic ray and in-beam measurements carried out at CERN at the PS T10 East Hall beam line, the timing performance of the various telescopes has been long investigated by a combined analysis of the results obtained from a large number of individual detectors operated for year-long data taking periods. The overall organization of the EEE project, with special emphasis on the timing aspects of the involved MRPC detectors, will be discussed in this contribution.

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Submitted by **PAGANO, Emanuele Vincenzo** <epagano@lns.infn.it> on **Sunday 20 July 2025**

Abstract ID : 22

The I-LUCE high power laser facility at INFN-LNS: status and perspectives for ultrafast applied physics

Content

A new high-power laser facility called “I-LUCE”(INFN Laser indUCed radiation production) will start operations at LNS-INFN (Laboratori Nazionali del Sud –Istituto Nazionale di Fisica Nucleare) in 2026.

The main laser system is composed of a combination building blocks from the primary oscillator to the compressor vacuum chamber. Each building block can be individually upgraded and continue to operate independently, allowing for fast scaling in total power and repetition rate for future performance upgrades. The system is based on Ti:Sapphire technology and will have two outputs: the first one will be a 50 TW beam line (25 fs, 1 J, 10 Hz) while the main beam line will be a 350 TW laser (25 fs, 8 J, 2.5 Hz) and upgradable to up to 500 TW. In each case variable pulse widths from 25 fs to a few tens of picoseconds are possible by control mechanisms in the main stretcher. I-LUCE will also count with a Coherent Astrella femtosecond laser providing laser pulses of up to 9 mJ of energy and 35 fs pulse duration at 1 kHz of repetition rate. Specific post-compression technology is being developed to arrive to sub-10 fs pulses with the laser that opens ultrafast-physics experiments to be developed. Ultra-fast physics experiments will involve the development of specialized measurement setups for plasma diagnostics including spectroscopy and interferometry for plasma density measurements.

I-LUCE will serve two distinct experimental areas known as E1 and E2. E1 will offer a unique combination of laser-generated plasmas with accelerated heavy ion beams, generated by a Superconducting Cyclotron and a Tandem (already installed at LNS), thereby providing opportunities for novel experiments in the fields of plasma physics, nuclear physics, and atomic physics. For moderate laser beam intensities (up to 50 TW), the experimental room E1 will be dedicated to conducting experimental runs focused on nuclear fusion and studying stopping power in plasma. Conversely, the E2 experimental room will be dedicated to both proton and electron acceleration. A specialized beamline designed to select, transport, and focus proton beams with energies between 5-60 MeV will be installed and optimized for radiobiological experiments.

A corresponding beamline for selecting electron beams will also be implemented. Furthermore, stand-alone experiments involving intense laser beams will be conducted to explore various studies, including X-ray laser generation and neutron production.

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Contribution Type: Oral

Status: SUBMITTED

Submitted by **PAGANO, Emanuele Vincenzo** <epagano@lns.infn.it> on **Sunday 20 July 2025**

Abstract ID : 23

Nanosecond-Synchronized Plasma Discharge in Gas-filled Capillary for Fast-Timing Radiotherapy

Content

This work demonstrates a high-current (~ 200 A) plasma discharge system with nanosecond-scale timing precision for medical and nuclear physics applications. The plasma is generated in a gas-filled capillary by a fast-rise-time discharge pulse (~ 200 A) from a resistance-inductance-capacitor (RLC) circuit, comprising a capacitor bank ($C_1 = 16.16$ nF, charged to 25 kV), parasitic inductance L , and the capillary's resistance R_p . A high-speed SCR (thyristor) switch, triggered by a 3–10 V gate signal, initiates the discharge through a gas-filled capillary, ionizing the gas to form a plasma column with a parabolic density profile—optimal for laser pulse guidance with minimal distortion. The controlled plasma density profile and sub-microsecond temporal evolution enable critical applications in advanced plasma acceleration schemes, particularly for laser-driven systems. In hybrid laser plasma acceleration (LPA) configurations, this discharge plasma serves as a precisely timed density transition layer for controlled electron injection, while the parabolic density profile facilitates low-distortion beam transport between laser wakefield acceleration (LWFA) modules. The well-characterized plasma conditions also provide diagnostic benchmarking opportunities for LWFA experiments, offering reproducible reference plasmas with nanosecond-scale timing accuracy for comparative studies of acceleration dynamics. These capabilities stem from the system's unique combination of tunable plasma parameters and exceptional temporal control, bridging discharge plasma technology with laser-plasma acceleration requirements. Through combined experimental measurements and circuit modeling, we characterize the time-dependent plasma evolution, including electron density and temperature dynamics, while active damping networks maintain stable, repeatable discharge characteristics. The system's precise temporal control enables critical applications in very-high energy electron (VHEE) or FLASH radiotherapy (FLASH-RT), where plasma formation must be synchronized with nanosecond accuracy to ultra-high-dose-rate beam delivery windows, and in nuclear physics experiments requiring precisely timed plasma sources for detector calibration. Currently being implemented at INFN-LNS, this platform addresses the growing need for time-resolved plasma sources in both medical and research applications, offering unique capabilities for fast-timing studies in radiation therapy and particle detection systems. The work highlights the importance of precision timing in plasma discharge systems and demonstrates successful integration of power electronics with plasma physics for time-critical applications.

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Contribution Type: Oral

Status: SUBMITTED

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Abstract ID : 24

Timing characterization of the NArCoS apparatus

Content

Simultaneous detection of neutrons and charged particles is essential in nuclear physics experiments involving stable and radioactive ion beams, particularly in studies of neutron-rich systems [1-2].

The NArCoS (Neutron Array for Correlation Studies) apparatus, currently under development at INFN (LNS, CT, MI) within the framework of PRIN 2020 ANCHISE project, is designed to meet this experimental challenge [3-5]. The system consists of an array of EJ-276G plastic scintillator cells (3x3x3 cm³), each one optically coupled to a cluster of silicon photomultipliers (SiPMs). The NArCoS detection modules operate as proton-recoil plastic scintillators. For a given neutron energy, the recoil proton energy spectrum ranges from zero up to the incident neutron energy. Consequently, an accurate neutron energy determination could be performed by using the time-of-flight measurements, making high timing resolution a key requirement for the system [6].

This contribution reports on a detailed characterization of the system's timing performance, carried out using cosmic rays and radioactive sources.

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Contribution Type: Oral

Status: SUBMITTED

Submitted by **PAGANO, Emanuele Vincenzo** <epagano@lns.infn.it> on **Monday 21 July 2025**

Abstract ID : 25

The High Speed Differential Transmitter with 32 channels project

Content

In the field of high-granularity multi-detectors used in nuclear physics, signal transmission between the front-end and the data acquisition system plays a crucial role. The CHIMERA apparatus, consisting of 2384 detectors (1192 Cesium Iodide and 1192 Silicon), was originally equipped with a transmission network based on RSE (Referenced Single Ended) signals, supported by shielded unipolar cabling organized into groups and subgroups. Approximately a quarter-century after its commissioning, an upgrade of the cabling system became necessary to address mechanical issues related to the flanges and to improve signal quality, electromagnetic interference immunity, maintenance, and the transportability of the apparatus.

The High Speed Differential Transmitter with 32 channels (HSDT-32CH) project was developed to meet these needs by introducing a modular architecture composed of 40 HSDT-32 electronic boards. These compact, highly integrated units perform signal conversion from RSE to differential transmission (DIFF), ensuring an improved signal-to-noise ratio and greater immunity to disturbances. The use of 100 Ω differential cabling, which is more robust and compact than the previous setup, simplifies the internal structure and enhances connection efficiency. The HSDT-32CH boards are designed to be positioned as close as possible to the CHIMERA apparatus, in accordance with installation requirements within the scattering chamber and with effective solutions for dissipating the heat generated.

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Contribution Type: Poster

Comments:

for the CHIMERA coll.

Status: SUBMITTED

Submitted by **PAGANO, Emanuele Vincenzo** <epagano@lns.infn.it> on **Saturday 9 August 2025**

Abstract ID : 26

Time of Flight technique for online monitoring of laser-matter interaction in Inertial Confinement experiments

Content

Over the past two decades, there has been growing interest within the scientific community in the field of high intensity laser-matter interaction. Using laser intensity ranging from 10^{15} to 10^{23} W/cm², it is possible to accelerate ions from an irradiated target through mechanisms such as TNSA (Target Normal Sheet Acceleration), RPA (Radiation Pressure Acceleration) or the Coulomb Explosion phenomenon [1](#).

In general, the driving force behind these phenomena is the high intensity laser radiation, which either causes a rapid electron displacement or the complete ionization of the target. As a result, the ions, within the target, experience an intense electrostatic potential capable of accelerating them, especially protons, up to hundreds of MeV energies, with fluences reaching values of 10^{13} ions/str [2](#).

Exploring these acceleration mechanisms is of increasing importance due to their potential applications in ion acceleration and laser-driven nuclear fusion. As consequence, it becomes essential to monitor the laser-matter interaction in real time, as the entire process unfolds within hundreds of nanoseconds.

A valuable method for this purpose is the use of Time of Flight (ToF) detectors. In laser-driven experiments, diamond and silicon carbide (SiC) detectors are commonly employed as online diagnostics tools thanks to their fast response time and exceptional radiation hardness, ensuring reliable measurements even under extreme experimental conditions. It has been shown [\[3,4\]](#) that ToF signals, although not allowing direct identification of ion species, can, under certain assumption, be used to reconstruct the energy spectrum of protons. This provides valuable insights into the laser-matter interaction dynamics, especially considering that protons are often the most abundant and energetic species in the experiments.

Finally, due to their compact size, multiple detectors can be arranged to measure the angular distribution of the emitted ions, which is particularly useful for optimizing laser accelerated ion beams.

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Comments:

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Status: SUBMITTED

Submitted by **PAGANO, Emanuele Vincenzo** <epagano@lns.infn.it> on **Saturday 9 August 2025**

Abstract ID : 27

Design and validation of an integrated reference dosimetry and monitoring system for UHDR proton beams

Content

Ultra-high dose rate (UHDR) irradiation has gained increasing interest in recent years for its potential to induce the FLASH effect, a radiobiological phenomenon in which normal tissue toxicity is reduced while keeping the same tumour control probability. The FLASH effect has been consistently observed when large single doses (typically $\geq 8\text{--}10\text{ Gy}$) are delivered in ultra-short time frames ($\leq 200\text{ ms}$), with mean dose rates exceeding 40 Gy/s and instantaneous dose rates often surpassing 105 Gy/s . Such beam dynamics —characterised by intense pulses and steep temporal gradients—demand dosimetric chains with sub-microsecond temporal resolution and high linearity, capable of avoiding saturation and preserving signal integrity. We present the design and experimental validation of an integrated reference dosimetry and beam-monitoring system tailored for UHDR proton delivery. The system integrates three detectors, a Secondary Emission Monitor (SEM), a Dual-Gap Ionisation Chamber (DGIC), and a Faraday Cup (FC). The SEM and DGIC operate continuously to monitor dose rates, while the FC, designed with innovative geometric and electronic features, ensures dose calibration. Experimental tests with 62 MeV protons at INFN-LNS, spanning $20\text{--}230\text{ Gy/s}$, demonstrated high reproducibility and accuracy: the FC achieved a mean relative dose uncertainty of 2% , the SEM agreed within 1.4% with the FC, and DGIC uncertainties were reduced below 3% after collection-efficiency corrections. Furthermore, a Silicon Carbide (SiC) detector was preliminarily tested for the first time with 62 MeV UHDR proton beams to assess dose linearity and sensitivity. As a direct consequence of these promising findings, the PRAGUE (Proton RANge measure Using silicon carbidE) project was funded. Its main objective is to develop and characterise a multilayer SiC detector capable of real-time measurement of the Percentage Depth-Dose (PDD) distribution for proton beams in the $30\text{--}150\text{ MeV}$ energy range. The detector is designed to operate effectively in both conventional (107 pps) and high-intensity (1014 pps) regimes, with a dedicated readout system comprising 60 current integrators equipped with optimised amplification stages to ensure efficient charge collection even under FLASH irradiation conditions.

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Contribution Type: Oral

Abstract ID : 28

Key Note Speaker

The Multimodal Artificial Optical Microscope

Content

Fluorescence super-resolved optical microscopy has an incredible power and ability in producing large data set originated from biological samples by light interrogation and tunable in terms of spatial at temporal resolution down to the nano- and pico- scale, respectively.

Label-free methods based on phase and polarization light-matter interactions provide molecular information at a different spatial scale. The resulting multimodal data set is the core for developing an artificial microscope, boosted by artificial intelligence, aiming to transform a label-free interrogation of the sample into a molecular-rich fluorescence-based image.

Such an intelligent artificial microscope is AI-guided through a computational core based on supervised deep learning strategy having the ambitious target to create a robust virtual environment “to see “what we could not perceive before”. An interesting case study is related to the study of the relationship between chromatin organization and cell function.

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Contribution Type: Oral

Status: SUBMITTED

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